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DEVELOPING THE METERING UNITE OF THE PNEUMATIC PLANTER
1-THE FACTORS AFFECTING SEED-METERING UNITE PERFORMANCE

Ismail, Z. E.
Ag. Eng. Dept. of Mansoura Un., Egypt.
Email: Ismailze221@mans.edu.eg

ABSTRACT

This work represents one of the out comes from a projects financed by El-Mansoura University researches unit (title of: Developing the metering unites of the pneumatic planter). The use of vacuum seed-hold for small seeds is identified under two different pitch circle radii of holding holes on seed metering unites and also under two different holes numbers. The span between the two consequently holes on the circumference of seeding disc device (δS) is considered a major independent variable used to reduce the imbrications between the seed holds number and seed holding radius. The (δS) is considered as the control factors during designing the seeding disc device in pneumatic planters. The theoretical relationship to determine the total amount of vacuum pressure required to hold the seed was identified. The radius of seeding disc is inversely proportion to the holding force meanwhile; the seed mass, radius of devices seeding disc and the crosses section area of the single hole of the seeding device are directly proportional. The inclination of practical and theoretical seed holding pressure may be ranged from 5 to 10 times of theoretical holding pressure. The 20 rpm and (δs) of 0.314 is be better than the other operation factors. But to realize the (δs) = 0.0314, it may be found at the pitch circle radius of holding holes on feeding disc device "R" = 15 cm and number of holes distributed on the circumference of seeding disc device (No) = 30 holes or at "R" =12.5 cm and (No) = 25 holes or at "R" = 10 cm and (No) = 20 holes.

Keywords: planter, seed device, pneumatic, single seed disc and systems analysis of seed feeding

INTRODUCTION

In crop production, the mean condition for high productivity depends on seed holding in the single seed-metering unit of a pneumatic planter. Although there are many planters having many different seed metering units, the application of the pneumatic single seed planters has rapidly increased by reason of the fact that their seedling performance is better than that of the others (Zelihe–2003).

The use of vacuum seed-pickup for small, irregularly shaped vegetable seeds, however, presents special problems, of which the main ones are:

a-Because the seeds are small, orifice sizes must be very small (in the range of 0.025mm diameter) to pickup one seed at a time. These small orifices permit only a small gripping force to be applied to the seed. Even more serious is the fact that orifices of this size may be very easily clogged by a particle of seed or soil dust.

b-The small gripping forces allow seeds to become easily dislodged from the orifice. The dislodging force result from differences between the velocity of the seeds and that of the orifice, as well as the friction involved in moving the gripped seed through the stationary seed supply.

c-Some vegetable seeds, such as lettuce or onion have one end that is pointed. A vacuum orifice is small enough to hold only one lettuce seed, by gripping its side surface can hold several seeds with pointed ends which are presented to the orifice. Thus this sort of irregularity in seed shape makes seed singling with a vacuum pickup difficult.

FMO (1981) said that the air system, pressure or vacuum, may be used to meter many different kinds of seeds. The changes required to go from one crop to another involve matching the size openings in the metering wheel or drum to the seed. Another requirement is matching the pressure differential to the density or mass of the seed. While, EL-Shal (1987) showed that the commonly used volumetric metering systems would not sufficiently meet the objectives of the research. Study was carried out to determine the minimum nozzle air velocity to lift up one seed, assuming that the seed closes the nozzle completely. This assumption is not fare because of the suction air force able to pick up the seed if the suction force is largest than the exhaust force.

The holding seeds in pneumatic disc planter face many factors affecting the holding force (ismail-2004). The shape and size of seeds, the cells disc shape and its diameter and the radius of single seed metering disc are considered as the main static factors influence the holding force. While, the amount section pressure, angular acceleration of metering disc, seed mass and liner velocities of planter are considered as the dynamic factors.

EL-nakib (1975), Bracy-RP et al. (1999), Srivastava A. E. (1995) and Singh R. C. el al. (1999) studied the effect of the shape of the holes, peripheral velocities, vacuum pressure, hole area on the number of holding seeds, numbers of the empty hole. The derivation of vacuum negative pressure required for holding seeds was invested by Morrison (1988). The resultant force (R) acting upon the seed due to centrifugal fore (C_r) and the weight of seed (mg) could be estimated as follow:

$$R = \sqrt{\sum (f_X)^2 + \sum (f_Y)^2}$$

Where, $\sum F(x)$ and $\sum F(y)$ are the total force acting upon seed in "x" and "y" axes respectively.

The vacuum pressure losses inside pneumatic planter may be arranged due to the design feature of the feeding device and also due to the air dust ratio in the inlet vacuum valve (ismail-2004). To overcome the vacuum losses, the required suction force that realizes a good holding during the operation time of the feeding seeds device must be determine.

Therefore, this paper aims to:

1- Study the effect of shape and radius of feeding disc on the seeds holding force.
2- Determine the disc liner speed that realizes the best operation for the single seeding disc.

3- Identify the best number of holding holes with a suitable pitch circle radius of holding holes on disc device.

THEORITICAL INVESTIGATION

The seed holding forces

The seed held on holes of the seed plate caused a pressure change, the vacuum pressure in this case may be upon the following forces as shown in Fig.(1). Under the up stares condition, the dynamic forces upon the single seed on the side of seeding devices may be equal to the vacuum pressure on the anther one.

Then,

$$C_f = m\,g + \mu\,N_1 \qquad (1)$$

$$N_1 = Fs \qquad (2)$$

Where:

C_f : the centripetal force, N

m : the single seed mass, Kg

g : the gravitational acceleration , m/s^2

μ : the coefficient of friction,

N_1 : the normal force on the seed, N

F_s : the amount of force required to hold the single seed, N

By indemnification the Eq.2 in Eq.1, then

$$C_f = m\,g + \mu\,F_s \qquad (3)$$

Also, by indemnification the value of the centripetal force in Eq. 3, then

$$m\,\omega^2\,R = m\,g + \mu\,F_s$$

$$F_s = \frac{1}{\mu}[m\,\omega^2\,R - m\,g] \qquad , N \qquad (4)$$

Where:

ω : The seeding disc angular speed

R : The pitch circle radius of holding holes on disc device, m

In case of number of holes (N_o) distributed on the circumference of seeding disc device, then the total forces (F_{st}) may be equal:

$$F_{st} = \frac{N_O}{\mu}[m\,\omega^2\,R - m\,g] \qquad (5)$$

The amount of vacuum pressure required to hold the seeds on the seeding disc device, "P" may be equal:

$$F_{st} = P\ .\ A$$

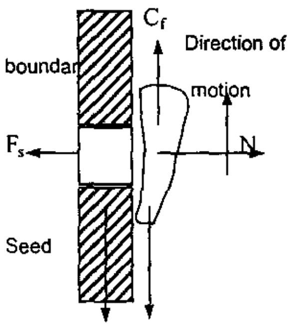
$$F_{st} = (P_a - P_n)\,.\,A \qquad (6)$$

Where:

A : the project area of the seed = $\pi\ R^2$,m^2

P_a: the absolute pressure, P_a

P_n: The vacuum pressure, P_a



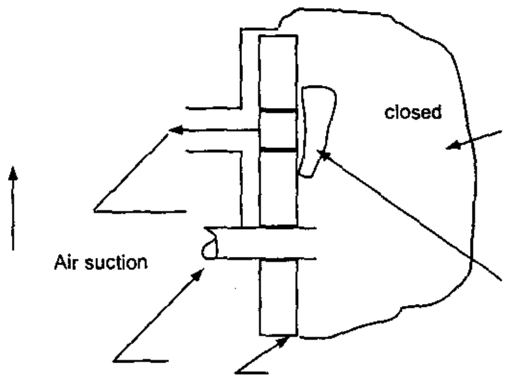


Fig.(1-a): Forces acting on a seed held in a pneumatic planter

Fig.(1-b):The forces distribution at free balancing during momentum seed holding

By substituting the Eq. 6 in Eq. 5, then

$$P_a - P_n = \frac{N\underline{\underline{o}}}{\mu} \frac{(m\,\omega^2 R - m\,g)}{\pi R^2}$$

$$P_a - P_n = \frac{N\underline{\underline{o}}}{\mu} \frac{m}{\pi}\left[\omega^2 - \frac{g}{R^2}\right] \quad (7)$$

The Eq. (7) may be formulate as follows,

$$P = C_1 \,.\, \frac{m}{\mu R}\left[R\omega^2 - \frac{g}{R}\right] \quad (8)$$

Where:

$$C_1 = \frac{No}{\pi}; \quad \omega = \frac{2\pi n}{60}, \quad and \quad P = P_a - P_n$$

By substituting the revolution number of seeding disc (n) in the eq.8, we found that:

$$\therefore\ P = C\,.\, \frac{m}{\mu}\left[\xi n^2 - \frac{g}{R^2}\right]$$

$$\xi = (\frac{2\pi}{60})^2 = 0.011$$

$$\therefore\ P = C\,.\, \frac{m}{\mu}\left[0.011\, n^2 - \frac{g}{R^2}\right] \quad (9)$$

Where:

P : The total amount of vacuum pressure required to hold the seed, P_a
n : The revolution number of seeding disc, number
R : The pitch circle radius of holding holes on feeding disc device, m
g : The gravitational acceleration , m/s^2

From above equation, the radius of seeding disc is inversely proportion to the holding force meanwhile; the seed mass, radius of devices seeding disc and the crosses section area of the single hole of the seeding device are directly proportional. Referring to the principle dimensions of seeds, its easy found the seed projected area and by substituting the vales parameters of each of m, R, g in Eq. 9 the theoretical vacuum pressure my be estimated. For example at mass of one seed of (76.35/1000)g; project area of seed of $22.2mm^2$; R= 0.124m and g =$9.81m/s^2$ then the vacuum pressure is found as 0.32kPa. According to the rotation of seed disc device, the theoretical analysis of suction forces upon the seed differs. Consequently, the values of vacuum are alternatives in according to the performance of seed situation on the disc.

On the other hand, the seed during angular motion in pneumatic planter are subjected to inertial and vibratory forces. Therefore, the seed holding pressure must always be appreciably greater than the above value in order to retain the seed throughout the seed metering and transport process. The inclination of practical and theoretical seed holding pressure may be ranged from 5 to 10 times of theoretical holding pressure. In the present study the seed holding vacuum were determined for maize and lentil seeds and values ranged from 1.0 to $2.5kP_a$.

The span between the two sequential holding holes

To study the effect of the seed devices disc diameters and the number of holes on the circumference of disc, the distance between the two sequential holding holes (δs) on the device disc is identified.

From principles relation, the amount of seeding out (Q seed/s) as a function between the two sequential holdings holes (δs) and the revolution number of seeding disc (n) may be equal

$$Q = \frac{2\pi R}{\delta S}\frac{n}{60} \text{ seed/s} \qquad 10$$

The above equation indicated that each of radii of feeding disc (R, m) and revolution number of disc (n, rpm) are direct proportional with the seeding out rate. But the distance between the two sequential holding holes (δs) on the device disc is inversely proportional.

The theoretical relationship between the quantity of seeds out (seed/s) and revolution number of feeding disc is illustrated in fig. 2. From the fig. it easy to realize the quantity of seeds out of 10seeds/s for seeding disc radius of 15cm. It may be found at 20rpm and (δs) = 0.0314 or at 23 rpm and (δs) = 0.037 or at 30 rpm and (δs) = 0.052.

On the others side, using the lowest disc speed improve the seed-holding on the disc. Then, the 20 rpm and (δs) of 0.314 is be better than the other operation factors. But to realize the (δs) = 0.0314, it may be found at the pitch circle radius of holding holes on feeding disc device "R" = 15 cm and number of holes distributed on the circumference of seeding disc device (N_o) = 30 holes or at "R" =12.5cm and (N_o) = 25 holes or at "R" = 10 cm and (N_o) = 20 holes.

MATERIAL AND METHODS

Two metering seeding disc were used under this investigation. The specification of the first pneumatic seed metering device are; the outer diameter of 248mm, thickness of 7 mm with equidistant holes at a distance of 231 mm pitch circle diameter.

The distance "δs" between the two sequential holes is 60.5mm, meanwhile, the second disc specification are 20 mm, 5 mm, 186 mm for disc outer diameter, for thickness and for pitch circle diameter of hole respectively. The holding seed is regulated by changing the number of holes on the metering disc or by changing the rotational speed of disc. The device was mounted to the vacuum retaining plate having 280 mm out side diameter and max. thickness of 40 mm for the first device ,while the second device having 250 and 36 mm of the above dimensions respectively as shown in fig. 3.

The investigated device was laboratory tested in Lab of Agric. Engineering department. The lab was supported by test-trolley. The test-trolley consists of three meanly parties, namely, the soil-bin, the mobile trolley and the transmission systems as shown in Fig. 4. The soil bin having a basin made from iron sheet with channel form. It is equipped with 6 U-section stands to carries the basin. The basin is denominated the soil bed.

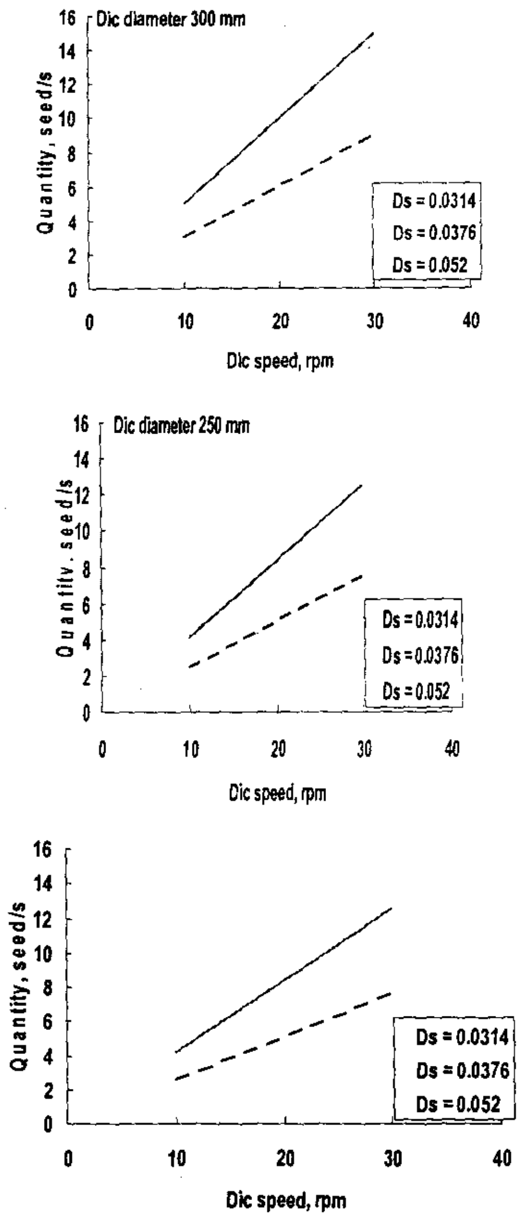
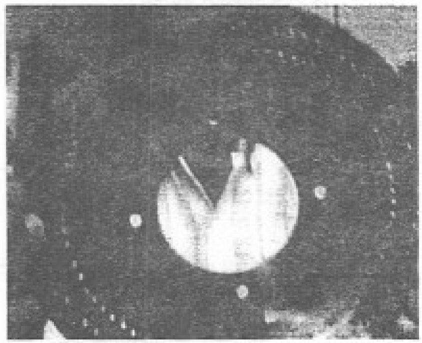


Fig. (2): The theoretical relationship between seeds out quantities and the seeding device speed.



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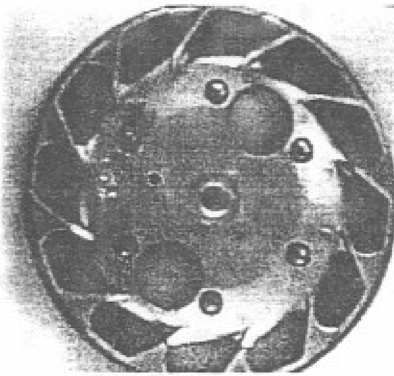

B): suggest by "Ismail, Z. E."

Fig.(3): The metering disc device

The mobile trolley is considered the base at which the investigated device tied on it (figs.- 5and 6). The motion was supplied to trolley by close transmission wire system (Fig.7). To over com the trolley motion resistance, four bearing were fixed on the rod of soil bin. The case of bearing was designed to easy run on the two parallel rail rods. The test-trolley was powered by electrical motor of 10 kW, which transmit the motion to the trolley by two individual reductions gear box to simulate the speed of the planting seeds in the field.

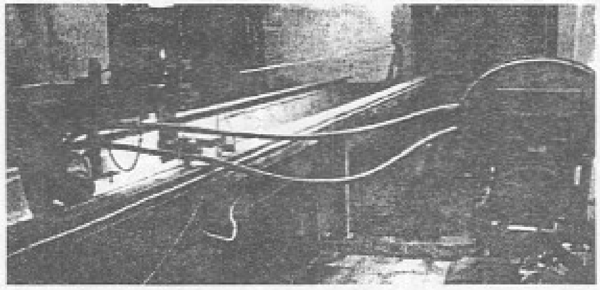

Fig.(4): The test-trolley lab (Ismail 2004)

The device was connected to the test-trolley laboratory (fig.5). Through chain and sprockets, a drive wheel was connected to the device system to provide rotation to the seed disc; the vacuum pressure was created by vacuum fan connected with the electric motor of 2.0 kW. The amount of vacuum pressure was regulated with controlled pressure valve at different levels of 1.0; 1.5; 2.0; and 2.5kPa.

The rotating seed disc convey the seeds attached to the seed holes under negative pressure and dropped only when the holes passed through the baffle that is related to the suction pressure. To prevent the seed entering the seed hole and also to avoid multiple seeds pick up by metering disc.

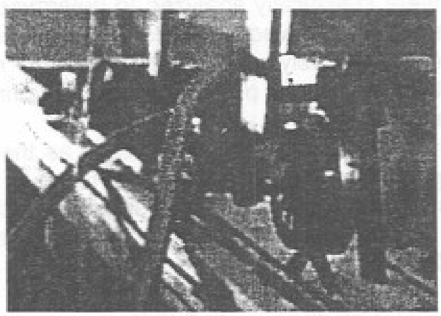

Fig.(5): The mobile trolley

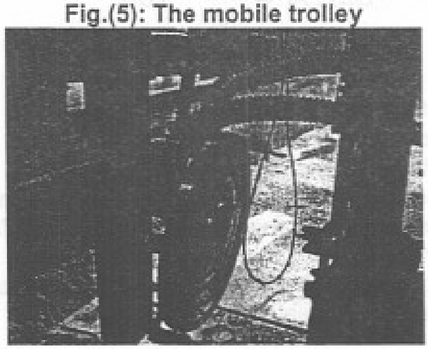

Fig.(6): The case of metering device

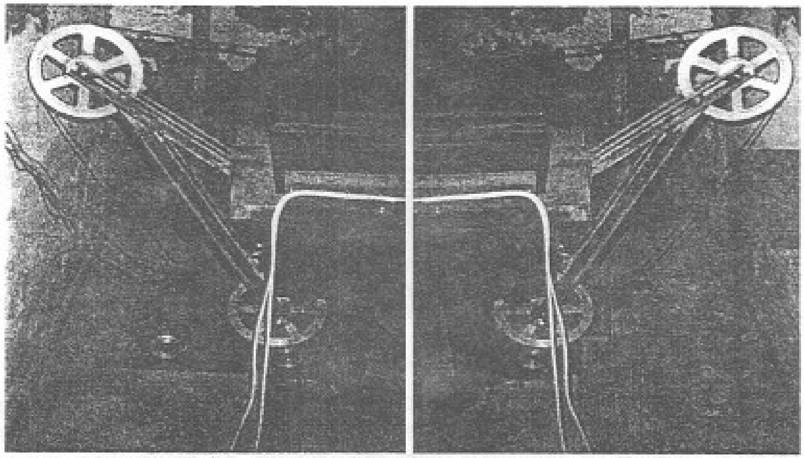

Fig.(7): The close transmission wire system

For optimization of the performance of the investigated pneumatic device experiments were conducted with four peripheral speed of metering disc of 0.28; 0.39; 0.48; and 0.59m/s which realized the revolution number of the first disc of 23.4; 32.2; 39.7; and 48.8 rpm and for the second disc of 28.76; 40.01; 49.3; and 60.6 rpm respectively. The tests were replicated three times for each whole number of disc devices.

The data were statistically analyzed to determine the effect of number of hole of the seed device, vacuum pressure and linear speed of disc on performance indices, namely mean seed spacing, miss index, multiples index, and quality of feed index, precisions in spacing and seed rate.

Seed miss index, (Sm, %)

The seed miss index could be considered as the first indicator for the seed disposing performance. It was estimated for each treatment by counting the number of hole/sells that have no seeds and counting the number of the used holes/sells in each treatment. Then the percentage of miss index can be calculated as follows:

$$Sm,\% = \frac{B_n}{M} * 100 \qquad (11)$$

Where:

Sm = The percentage of seed miss index, %

M = The total number of the used holes/sells

B_n = The number of holes that have no seeds

The seeds multiples index, (Smu %)

The seed double ratio could be considered as the second indicator for the seed disposing performance. It was estimated for each treatment by counting the number of holes that have more than one seed and counting the number of the total holes in each treatment. Then the percentage of seeds multiples index can be calculated as follows:

$$Smu,\% = \frac{A_n}{M} * 100 \qquad (12)$$

Where:

Td, % = The percentage of seeds multiples index, %

A_n = the number of holes that have more than one seeds

The quality of feed index (UH, %)

The uniformity of the seed in row could be considered as the third indicator for the seed disposing performance. It was estimated by calculating the seed miss index and the seed multiples index. Then the percentage of the quality of feed index in row can be calculated as follows:

$$UH,\% = 100 - (Sm,\% + Smu,\%) \qquad (13)$$

The amount of seed rate (Q,seed/s)

The actual amount of seed rate was measured according to the equation of

$$Q = \frac{M_1 \times 1000}{\psi}, \; Seed/s \qquad (14)$$

Where:

M1: The mass of seed out from devices per certain times, g

Ψ : The mass of 1000 seeds, g.1000^{-1}

The SAS programming was used to analyses the obtained data under different variables.

RESULTS AND DISSCUTION

Effect of the vacuum pressure on the seed dispersions

Experiments was proceeded to test and evaluate the performance and efficiency (seed space, cm; seed miss, %; seed multiple, % and quality of feed indices) of a vacuum pressure of seeding machine (vertical disc of metering device) in laboratory. Fig. (8) illustrates the relationship between the seeding device speed (m/s) and the seeding spacing at different holding vacuum pressure (1.0; 1.5; 2.0 and 2.5kPa).

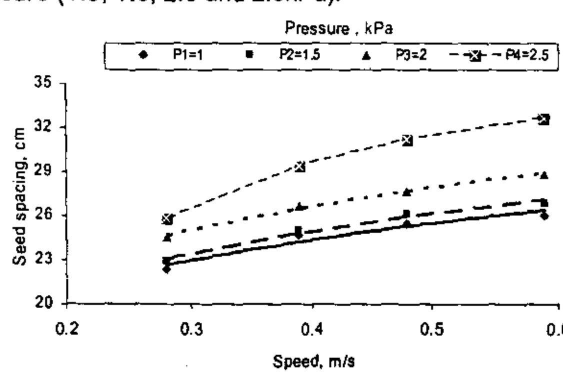

Fig. (8): seed spacing via seeding device speed

The general trend of this relationship is that the seed spacing increase with the increase of planting speed and holding vacuum pressure. Increasing the holding vacuum pressure; the average of seed spacing between the seeds on line become near to the theoretical adjusted span (25cm). The maximum seed dispersion was 32 cm at holding disc speed of 0.6 m/s and vacuum pressure of 2.5kPa, while, the minimum value was 23 cm at holding disc speed of 0.28 m/s and vacuum pressure of 1.0kPa. The theoretical seed spacing (25cm) was found at 0.38 m/s disc speed and vacuum pressure of 2.0kPa or at 0.55 m/s device disc speed and vacuum pressure of 1.5kPa. But increasing the seed disc device speed has a negative effect on the seed missing and double.

The first parameters to evaluate the seeding devices performance is the seed miss index in percentage. The relationship between the seeding device speed (m/s) and the seed miss index at different holding vacuum pressure (1.0; 1.5; 2.0 and 2.5kPa) was identified as shown in Fig.(9). The seeding device speeds (m/s) have a major effect on the seed miss index. The general trend of this relationship is that the seed miss index "%" increases with the increase of planting speed and decreases with the increase holding vacuum pressure. The maximum seed miss index was 9.6% at holding disc speed of 0.6 m/s and vacuum pressure of 1.0kPa, while, the minimum value was 0.23% at holding disc speed of 0.28 m/s and vacuum pressure of 2.5kPa.

A regression type of power analysis was applied to relate the change in seed miss index under the effect of seeding disc device speed at different vacuum pressure. The obtained regression equations were in the form of:

$Sm = 27.142\ X^{1.99}$ $R^2 = 98.73\%$ at vacuum pressure of 1.0kPa,
$Sm = 19.464\ X^{1.94}$ $R^2 = 99.29\%$ at vacuum pressure of 1.5kPa
$Sm = 22.493\ X^{2.64}$ $R^2 = 99.97\%$ at vacuum pressure of 2.0kPa
$Sm = 24.722\ X^{3.45}$ $R^2 = 94.94\%$ at vacuum pressure of 2.5kPa

Where:

Sm : the seed miss percentage,%
X : the seeding disc device speed, m/s

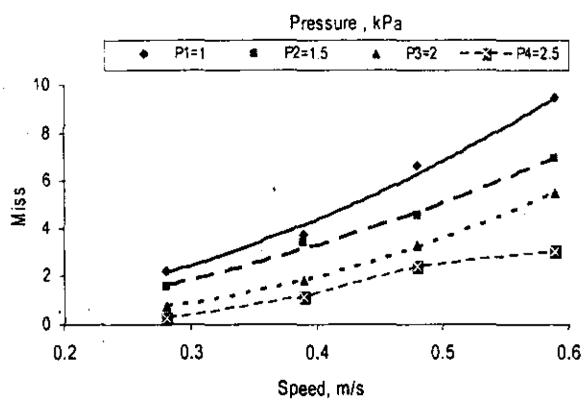

Fig. (9): seed missing via seeding device speed

The second parameter to evaluate the seeding devices performance is the seed multiple index. The relationship between the seeding device speed (m/s) and the seed multiple index at different holding vacuum pressure (1.0; 1.5; 2.0 ard 2.5kPa) was identified as shown in Fig.(10). The general trend of this relaticnship is that the seed multiple index increases with the increase of seeding disc speed and with the increases holding vacuum pressure. The maximum seed multiple index was 10.57% at holding disc speed of 0.6 m/s and vacuum pressure of 2.5kPa, while, the minimum value was 1.25 at holding disc speed of 0.28 m/s and vacuum pressure of 1.0kPa.

The uniformity of the seed in row was evaluated by "UH" index. Fig (11) illustrates the function between the seeding device speed (m/s) and the vacuum pressure of seed holding (P). There is a negative relationship between the seeding device speed and the uniformity of the seed (UH,%). Also, increases the vacuum pressure decrees the UH,%. This phenomena may be explain that, by increasing the vacuum pressure the amount of seed multiple index increases consequently, the UH% decreasing.

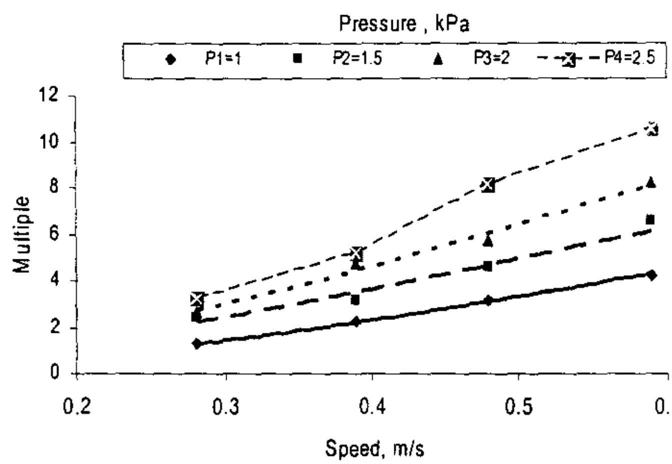

Fig. (10): seeding multiple via seeding device speed

Effect of the pitch circle radius of holding holes on seed dispersions

The relationship between the seeding device speed and the distance between the seeding in row is drawing in Fig.(12) under two different of the pitch circle radii of holding holes (R1=231mm and R2=186mm). In general, increases the pitch circle radius of holding holes increasing the span between the two sequential seeds in row for all treatment under different vacuum pressure. But, at vacuum pressure of 2.5kPa the seeding span was greater than the others.

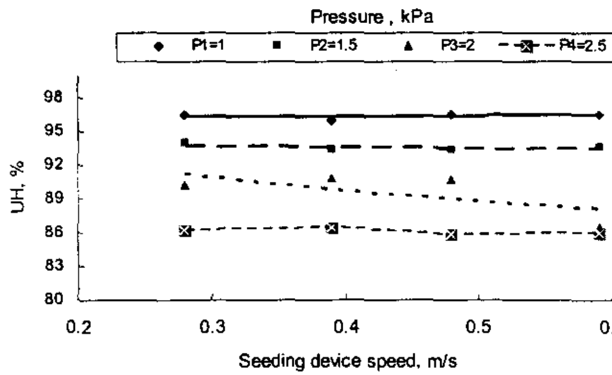

Fig. (11): The uniformity of seed via seeding device speed

For example, to realize the distance between the seeding in row of 25 cm, may be found at 0.35m/s at R1=231mm and P=1.0kPa or at 0.59m/s at R2=186mm and at the same pressure. While increasing the pressure to 1.5 kPa the 25cm distance between the seeds may be found at 0.30m/s and at 0.48m/s for R1 and R2 respectively. The same results may be found at 0.25m/s and at 0.37m/s for P=2.0kPa and for R1 and R2 respectively. While at P=2.5kPa, the 25cm distance may be found at 0.22 and 0.25m/s respectively.

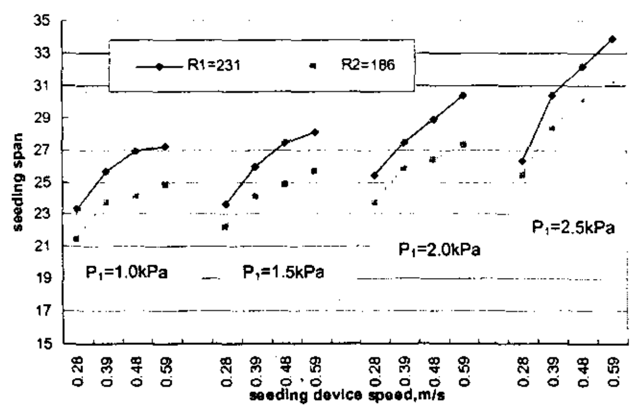

Fig. (12): The relationship between the seeding span and seeding device speed

A regression type of polynomial analysis was applied to relate the change in seeding span (Sp) under the effect of each of seeding disc device speed (S) and different vacuum pressure (P) at different pitch circle radii of holding holes (R1=231 and R2= 186mm). The obtained regression equations were in the form of:

At R1= 231mm:
$$Sp = 0.429 + 3.475 P + 83.932 S - 75.978 S^2 \quad R^2 = 98.54\%$$
At R1= 186mm:
$$Sp = 0.443 + 3.645 P + 76.553 S - 72.126 S^2 \quad R^2 = 98.33\%$$

The amount of seeding rate (seeds/s)

Fig.(13) shows the average of obtained results for amount of seeding rate (seeds/s) as affecting by the metering devices speed for two pitch circle radii of holding holes (R1=231 and R2=186mm) at vacuum pressure of 2.0kPa. Generally, the seeding rate is directly proportional to metering device speed. As the results indicated above that the best span between seeding in row is 25cm and it may be found at 0.22m/s and 0.25m/s for R1and R2 respectively. Then from fig.(13) and at 0.22 and 0.25m/s, the seeding rate were 1.98 and 3.9 seed/s at R1and R2 respectively.

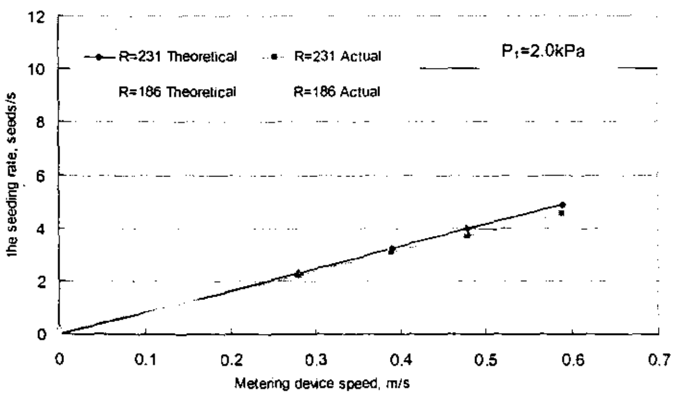

Fig. (13): The relationship between the seeding rate and seeding device speed

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١-العوامل المؤثرة علي اداء وحدة التلقيم

زكريا إبراهيم إسماعيل
قسم الهندسة الزراعية – كلية الزراعة – المنصورة

تعتبر هذة الورقة احدي مخرجات المشروع الممول من وحدة البحوث بجامعة المنصورة لمشروع تطوير وحدة تلقيم الزراعة بالهواء. تم استخدام جهازين للقط البذور باستخدام سحب الهواء من غرفة التلقيم ذات اقطار مختلفة بالنسبة لوحدة التلقيم وايضا ذات عدد من الفتحات المتباينة والموزعة علي مسافات منتظمة لمحيط القرص التلقيم. نظريا تم تحديد الأرتباط بين تلك العوامل بأستخدام المعامل (δS) وتأثير ذلك علي انتظام توزيع البذور (معامل المسافة- معامل الغياب-معامل لقط اكثر من بذرة- معامل جودة التلقيم) تحت تأثير كل من سرعة قرص التلقيم – ضغط سحب البذور). تم استنتاج المعادلة النظرية التي تربط القوي الازمة للقط البذور بالنسبة لي نصف قطر قرص التلقيم ولصعوبة قياس تلك القوي استخدمت تاثير القوي كدالة في انتظام توزيع البذور. يمكن القول ان معايرة تلك العوامل امكن الحصول علي افضل انتظام توزيع للبذور.